Brain Transfer for the Analysis of Cortical Data

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The cerebral cortex is the largest part of the human brain and is critical for a variety of sensory, cognitive, and motor functions. Though the functional and anatomical organization of cortex are related, the complexity and variability of the folds makes comparisons across individuals challenging. Neuroimaging often requires accurate algorithms for matching cortices. Efficient mathematical frameworks are consequently sought for analyzing data on inflated cortical surfaces, and for transferring corresponding anatomical and functional maps between subjects. Standard methods typically rely on anatomical features, including sulcal depth, to drive the alignment across individuals (Fischl et al. 1999). Recent methods can align subjects based on the similarity of neural activity patterns (Conroy et al. 2013). These present approaches typically treat each task separately and can be computationally expensive, requiring several hours to process a single subject.

Here, we propose *Brain Transfer*, a spectral shape framework that provides fast point matching with confidence regions, and transfers of functional maps, within minutes of computation. Spectral methods have the advantage of capturing the underlying intrinsic geometry of shapes. We improved over previous spectral approaches by addressing the instabilities of geometrical harmonics (Lombaert et al. 2013). The improved normalization is key to process and analyze functional data on matched cortices. More precisely, our contributions consist of (1) the optimization of a spectral transformation matrix, which combines both, surface correspondence and normalization of geometrical harmonics, and (2) a localized spectral decomposition of functional data, via focused harmonics. This spectral transfer provides a robust formulation for spectral methods and naturally handles sign changes as well as differences across Laplacian eigenvectors. The novel focused harmonics capture the essentials of the intrinsic geometrical properties in a confidence area, and form a basis for reconstructing the shape of cortical surfaces and functional maps across subjects. Thus, Brain Transfer enables the transfer of functional data across interchangeable cortical surfaces, accounts for localized confidence, and gives a new way to perform statistics on surfaces.

When matching cortical surfaces based on sulcal depth, we achieve similar accuracy in a fraction of the time compared to spherical-based methods. We outperform standard spherical-based methods when matching functional data within the visual cortex.

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